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ENVIRONMENTAL CRITERIA DETERMINATION
FOR FUEL AIR EXPLOSIVE (FAE)
(SOUTHEAST ASIA)

by

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ABSTRACT. The stockpile-to-target sequence for FAE with emphasis on use in Southeast Asia is discussed. The criterion associated with manufacture in the United States, transportation to, and use in Southeast Asia are presented. Environmental criterion are presented where known. Where unknown, assumptions or projections are given based on the author's best educated guess. Technological support is given for the criterion presented. The report includes 1 figure and 3 tables.



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FOREWORD

This report describes the first step in the process of developing an environmental criteria for the actual service life and usage of fuel air explosives with emphasis and limitations for use in Southeast Asia.

The author has presented environmental criteria for the complete stockpile-to-target sequence for fuel air explosives based in part on measured data and on his personal experiences and discussions with personnel working with actual environmental conditions. For environmental criteria that at present is unknown or untested, the author has given his "best estimate". The technological basis for the best estimate is given in the report.

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INTRODUCTION

The ground rules for the first Fuel-Air-Explosive (FAE) weapon system were such that it was to be developed for use in Southeast Asia (SEA). The usual design environment is worldwide; however, to facilitate a rapid introduction of FAE into the Fleet for use during the Viet Nam emergency, the less restrictive environmental parameters were authorized if meeting worldwide environments imposed schedule restrictions.

The question still remained as to the differences in environmental extremes to be encountered between worldwide and SEA environments. This report is the document in which the SEA ordnance extremes are presented. It can be seen that there are some differences; mainly in the ordnance temperature extremes. The other environments reflect generally worldwide extreme situations.

It must be recognized that any "theater" criteria determination must also recognize the continental United States parameters along with the specialized parameters of the specific theater. Therefore, the envelope of exposure to temperature extremes are generally wider in this report than they would be if the accounting was to be for SEA only.

USES OF THE REPORT

The information contained herein is not necessarily that which will be directly converted into specifications. In some cases the project manager may decide, for reasons of his own, that a "fudge factor" should be added. This is the prerogative of the project manager. The information herein reported is only the basis on which the design, qualification, and/or reliability specifications are to be written. In case of a need for designer or manufacturer requested waiver, the project manager will not be in difficulty by granting the change to the criterion limit herein stated. However, any waiver to a lesser criterion than herein stated values should be accompanied by an investigation of the in-Fleet penalties to be paid.

MAKE UP OF REPORT

The report consists of Introductory Material, Criteria, and Appendices. The information contained in the Introductory section delineates the uses and acceptable abuses of the report. The Criteria section delineates the true state-of-the-SEA environment and advances a projected environment as factual as is possible within the present state of investigations now underway. The Appendices in minor detail place the projections into context.

Each "number" that is advanced in the Criteria section is discussed in some detail in the appropriate Appendix. The Appendices are intended as a preliminary reference section. Any serious investigator can obtain from the Appendices the context and in some cases the source of the information given in the Criteria section. For a casual reader, a glance at the tabulated material in the Criteria section will suffice instead of laboriously reading the Appendices.

STOCKPILE-TO-TARGET SEQUENCE

There must be some way to determine what the use life of air-launched ordnance in reality is. The method herein used consists of graphically outlining the probable life of an air-launched unit as shown in Fig. 1. An investigation of Fig. 1 will indicate that no matter what the air-launched ordnance item may be, during its life span it will follow the diagram.

In general, the sequence starts at the component manufacturer level. It can be assumed that the components will be built in the manufacturing centers of industrialized nations of the world. It is also evident that an emerging primitive nation would have neither the capability nor the skilled workmen to construct the component parts of modern weaponry. The components will be shipped from the manufacturer to assembly depot by only four different modes of transportation. These are by truck, rail, ship, or air. No animal drawn or primitive transportation need be investigated since the type of nation producing sophisticated weapons has advanced beyond such transportation methods. The assembly depot can be assumed to be located in a manufacturing complex, or if in a remote location it will have the equivalent facilities of a modern manufacturing complex. All sub-component storage will be in some type of covered area, either above ground storehouses or earth covered igloos. Therefore, the component will be protected from the adverse effects of exposure to the weather. On assembly, the units will be packaged and palletized for delivery to the Fleet. If manufactured in the United States, the unit is then shipped via truck, rail, or air to one of the established Naval Ammunition Depots (NAD), situated within the continental boundaries. Once at the NAD, the unit will be placed in a standard "Explosive Hazard Magazine" as per instructions delineated in NavWeps OP-5, Vol. I. Again, there will be no outside storage and a very small chance of storage in above ground storehouse facilities. From the continental United States storage depot, the item will be sent to either (1) an aircraft carrier, (2) overseas for storage or use, or (3) stored on board an ammunition ship. In the vast preponderance of times the unit will be transported via ship to a forward area or loaded on board an aircraft carrier for a tour of duty.

During wartime the use of civilian merchant ships is a good probability. Therefore, the use of non-Naval ships and the inherent chance

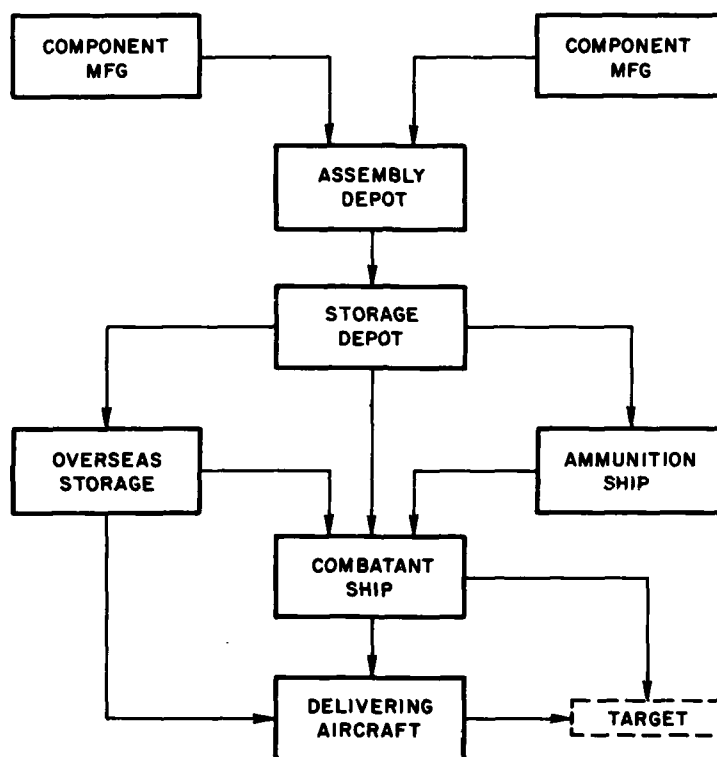


FIG. 1. Stockpile-to-Target Sequence.

of cargo mishandling must be recognized. Once at a forward storage area, there are three storage modes possible. The first is igloo storage, second is above ground storehouse or primitive covered storage, and the third is primitive dump storage. It has been observed even during the first hectic days of the Viet Nam emergency that at the forward storage depots, the air-launched rocket motors and components received preferential treatment. Where there were storage igloos, the bombs, gun ammunition, ballistic rockets and some pyrotechnics were dump-stored to provide room for the more sophisticated air-launched guided missile components. This is only an indication, but a strong one, that the air-launched rocket will, whenever possible, receive preferential treatment. FAE will in all probability be treated as any free fall ordnance. It will probably be delegated to outside storage if inside storage space is at a premium.

The forward storage situation is the most severe portion of the stockpile-to-target sequence that the weapon can be expected to experience.

Another flow sequence (Fig. 1) shows the unit being loaded onto an ammunition ship for at-sea-transfer to an aircraft carrier. This operation has become increasingly popular in the limited war situation where the aircraft carrier is used more as a stationary Naval Air Station than a tactical weapon system as in World War II.

The land counterpart of the aircraft carrier is of course the Marine Corps forward airfield. In a wartime situation, a forward airstrip will be cut from the terrain. Any natural hill and valley area will be used for dump storage of the explosive components. Usually there will be few or no pieces of elaborate handling gear or specialized tools and equipment.

Since the unit is to be used in both circumstances, it should be designed so it will be usable and function when air-carried from either situation. Therefore, the more stringent environmental considerations of the Marine Corps use should be given recognition. Instead of the antiseptic conditions of an aircraft carrier, the unit may sit in the sand, wind, and rain for a period of time before it is manhandled to the "hot line" and installed on an aircraft from which it is later launched.

A study of Fig. 1 will reveal that all variations of paths have not been discussed here. There are many possible combinations of the enumerated stations in the sequence; however, the other combinations would lead to no new environmental criteria that have not already been identified. Therefore, for brevity's sake, they have been omitted.

SURVIVAL VERSUS FUNCTION

The overwhelming majority of environmental specifications, weapon specifications, etc. make no note of the difference in probable conditions under which a unit must survive, and those under which it must function. From Fig. 1 the 15 column headings of Table 1 have been derived to classify the various types of exposure to which a unit may be exposed. It should be evident that in the situations as stated in the first 14 columns of Table 1 the unit must only survive intact so that it will fully function when called on to do so in column 15. This concept becomes very important when it is noticed that the majority of the extreme values for the listed environments occur in the first 14 columns. The much modified set of probable environments as set forth in column 15 are in fact the only set under which the unit must fully accomplish the design objective. The most important fall out of this concept is its effect on the design temperatures and firing temperatures of air-launched rocket motors. The design temperature must include the extremes shown under the dump storage column. The unit will not be called on to function in a storage dump. Therefore, the firing temperature limits will be much narrower since the launching aircraft's parameters and other modifying situations must be taken into account, all of which tend to modify the storage dump extremes. Also, the state-of-the-art requires the unit to be packaged for storage and shipment in a container. The unit is installed in this protective shell at least through column 9 of Table 1. In columns 10, 11, 12, 13, 14, and 15 there will be no container to protect the unit. This being the case, any developmental environmental testing should reflect this fact of life.

UNIT LIFE

The life of any air-launched unit will not be comprised of equal parts of the situations as presented in the columns of Table 1. A rough approximation of the breakdown of the life expectancy would be as follows:

	<u>% of lifetime</u>
Igloo or covered storage	85
Transportation	5
Ammunition and combatant ship	5
Dump storage	3
Air-carried	1

These values can be juggled each way by whomever would take the time; however, the fact remains that the vast majority of the life cycle of any air-launched unit can be expected to be storage. Therefore, any investigation of the environment of an air-launched item should be primarily

interested in the definition of the storage parameters. The "scare" values, or extreme criterion must be placed in a statistical context so that the assumption is not made that just because a given extreme has been measured, that it is a common occurrence. Conversely the statistical context may determine that the extreme situation may be in fact a very common occurrence. Until the extremes are measured and placed in statistical context, there will continue to be the same lack of knowledge on which to base critical environmental design decisions that exists today.

ASSUMED, PROJECTED ENVIRONMENTAL CRITERIA

Since all the theoretical discussions of environmental limits, without valid criteria, are of no use to the practical designer, tentative criteria will be presented in this section. The only justification for this section at this time is that someone, somewhere in the Navy system, must assume the responsibility for temporarily filling the information gap. When the environmentalist, who is closest to the problem, answers a truthful, "I don't know" to a specific environmental question, then the specification writer, who is far removed from the field, must make the decision. It must be stringently stipulated that the author "does not know" when filling in the unknowns of Table 1, to come up with Table 2. Table 2 reflects mainly educated guesses. Since the press of time and money require this type of information, Table 2 is at least the author's best projections for the FAE system.

The publishing of Table 2 in no way suggests that more work is not needed to make the data presented therein more realistic. In the critical functional areas of temperature and humidity, shock and vibration, investigation at best is not even beyond the primitive stage. (A thorough search of published and nonpublished data was made in order to find any authentic and valid information available. Appendix A presents the details of a literature search which proved to be extremely disappointing.) Those data that exist on temperature for example are, in the majority of cases, single measurements or measurement series. There has been no attempt to place the temperature work in a logical matrix or even state when, in the solar cycle, the exposure was accomplished. The science of statistics has not been allowed "in" on the criteria determinations. The "one shot" measurements of the past and present do not produce enough suitable data points so that the rules of probability can be applied. For example, a maximum dump storage temperature of 125°F is given in Table 2. There is a theoretical time of exposure limitation of 3 hours (maximum taken from actual recorded times), but nowhere is there a "probability of occurrence". The question remains: "Is this criterion reached daily, yearly, monthly, or only once every 10 years?". For a designer, the question is far from academic. The most direct way the Navy can answer the question is to provide measurements for a significant portion of a "solar cycle" to the statistician so that he can then apply the laws of probability, thus giving the designer a probability of occurrence.

TABLE 1. Environmental Criteria for FAE (South

	Transportation				Storage			8 At-Sea Transfer	9 St
	1 Truck	2 Rail	3 Ship	4 Air	5 Igloo	6 Covered	7 Dump		
Temp/time (High)	○	○	○	○	100°F for 4 hr	○	○	100°F for 8 hr	
Temp/time (Low)	○	○	○	○	30°F for 72 hr	○	○	30°F for 24 hr	
Relative Humidity	100% @ -10°F 95% @ +95°F 45% @ 120°F	100% @ -10°F 95% @ +95°F 45% @ 120°F	95% @ 40°F to 95% @ 90°F	100% @ -30°F to 50% @ 110°F	100% @ 0°F 95% @ 95°F 50% @ 100°F	100% @ -10°F 95% @ 95°F 45% @ 120°F	100% @ -20°F 95% @ 95°F 28% @ 140°F	100% @ 30°F to 20% @ 100°F	(
Rain	2 in/hr for 1 hr	None	...	...	None	Negligible	2 in/hr for 2 hr	2 in/hr for 2 hr	(
Ice and Hail	1 in/hr 2 in buildup	None	...	...	None	Negligible	1 in/hr for 1 hr	None	(
Snow	10 in/hr for 1 hr	None	...	...	None	Negligible	10 in/hr for 1 hr	None	(
Corrosive Atmosphere	○	○	○	○	○	○	○	○	(
Sand and Dust	○	○	...	...	○	○	○	...	(
Shock	*3.5 g for 25-50 m sec	*25 g for 11-18 m sec	*MIL-STD-901C values	Negligible	...	...	...	*15 ft per sec to steel	(
Drop No damage	1 ft to dirt	1 ft to rock	5 ft to bottom of hold	1 ft to concrete	1 ft to concrete	1 ft to concrete	2 ft to dirt	2 ft to steel	(
Vibration	±1 g for 1-60 cps	±2g - 10/60 cps ±5g - 60/500 cps	±0.4 g @ 5-55 cps	±3 g @ 20-500 cps	...	...	...	Negligible	(
R. F. Radiation Hazard	○	○	○	○	○	○	○	○	(

Weapon in Container

Weapon Must Only Survive

* Accepted but Unverified

○ No Accepted Data Available

A

Environmental Criteria for FAE (Southeast Asia).

6		8 At-Sea Transfer	Airfield		Aircraft carrier		Aboard aircraft		15 Launch to Target
1	7 Dump		9 Storage	10 Handling	11 Stowage	12 Handling	13 Helicopter	14 Propeller	
	○	100°F for 8 hr	○	○	○	○	○	○	○
	○	30°F for 24 hr	○	○	○	○	○	○	○
10°F 95°F 20°F	100% @ -20°F 95% @ 95°F 25% @ 140°F	100% @ 30°F to 20% @ 100°F	○	○	○	100% @ 40°F to 50% @ 110°F	○	○	○
e	2 in/hr for 2 hr	2 in/hr for 2 hr	○	○	...	...	○	○	○
e	1 in/hr for 1 hr	None	○	○	...	None	○	○	○
e	10 in/hr for 1 hr	None	○	○	...	None	○	○	○
	○	○	○	○	○	○	○	○	○
	○	...	○	○	○	○	○
	...	*15 ft per sec to steel	○	○	○	○	○	○	○
rete	2 ft to dirt	2 ft to steel	○	○	○	2 ft to steel	...	...	○
	...	Negligible	○	○	○	...	○	○	○
	○	○	○	○	...	○	○	○	○
			Weapon out of container						Weapon Must Function
Weapon Must Only Survive									
... Not Applicable									
7									

B

TABLE 2. Assumed Preliminary Environmental

	Transportation				Storage			8 At-Sea Transit
	1 Truck	2 Rail	3 Air	4 Ship	5 Igloo	6 Covered	7 Dump	
Temp/time (High)	120°F/2 hr to 90°F/24 hr	120°F/2 hr to 90°F/24 hr	110°F/4 hr	90°F/16 hr	100°F/1 hr	115°F/4 hr to 90°F/24 hr	125°F/4 hr to 90°F/24 hr	100°F/8 hr
Temp/time (Low)	-10°F/36 hr	-10°F/3 hr	-30°F/4 hr	40°F/24 hr	30°F/72 hr	60°F/24 hr	60°F/24 hr	60°F/24 hr
Relative Humidity	100% @ -10°F 95% @ 95°F 45% @ 120°F	100% @ -10°F 95% @ 95°F 45% @ 120°F	100% @ -30°F 50% @ 110°F	95% @ 40°F 95% @ 90°F	95% @ 95°F 50% @ 100°F	100% @ 60°F 95% @ 95°F 48% @ 115°F	100% @ 60°F 95% @ 95°F 40% @ 125°F	100% @ 100°F 95% @ 95°F 20% @ 125°F
Rain	2 in/hr direct impingement	None	DNA	DNA	None	None	2 in/hr direct impingement	2 in/hr direct impingement
Snow	None	None	DNA	DNA	None	None	None	None
Ice and Hail	None	None	DNA	DNA	None	None	None	None
Corrosive Atmosphere	Negligible	Negligible	Negligible	Negligible	1/4 in H, R, S, per year	1/4 in H, R, S, per year	1/4 in H, R, S, per year	Total sea immersion
Sand and Dust	Direct impinge- ment, 50 mph 0,001 to 0,125 in. dia.	Negligible	Negligible	DNA	None	Direct impinge- ment, 45 mph wind, 0,001 to 0,125 in. dia.	Direct impinge- ment, 45 mph wind, 0,001 to 0,125 in. dia.	DNA
Shock	3, 5 g 25-50 ms	25 g 11-18 ms	Negligible	MIL-S-901C	DNA	DNA	DNA	15 ft/sec
Drop No damage	1 ft to bed or deck	1 ft to bed or deck	1 ft to floor	5 ft to hold	1 ft to floor	1 ft to dirt	2 ft to dirt	2 ft to deck
Vibration	+1g @ 1-60 cps	+2g @ 10-60 cps +5g @ 60- 500 cps	3 g @ 20- 500 cps	±0, 4g @ 5-55 cps	DNA	DNA	DNA	Negligible
R. F. Radia- tion Hazard	Less than 1 v/m	Less than 1 v/m	1 to 2 v/m	Less than 1 v/m	Less than 1 v/m	Less than 1 v/m	Less than 1 v/m	Less than 1 v/m

Weapon in container

Weapon Must Only Survive

DNA - Does Not Apply

H, R, S, - Hot Rolled Steel

A

Eliminary Environmental Criteria for FAE (Southeast Asia).

	7 Dump	8 At-Sea Transfer	Airfield		Aircraft carrier		Aircraft carried		15 Launch to Target
			9 Storage	10 Handling	11 Stowage	12 Handling	13 Helicopter	14 Propeller	
	125°F/4 hr to 90°F/24 hr	100°F/8 hr	125°F/4 hr at 90°F/24 hr	125°F/4 hr to 90°F/24 hr	90°F/16 hr	110°F/2 hr	125°F/30 min to 70°F/2 hr	125°F/30 min to 60°F/2 hr	125°F/90 sec
	60°F/24 hr	60°F/24 hr	60°F/24 hr	60°F/72 hr	60°F/2 hr	70°F/2 hr	0°F/2 hr	0°F/2 hr	0°F/90 sec
60°F 85°F 15°F	100% @ 60°F 95% @ 95°F 40% @ 125°F	100% @ 60°F 95% @ 70°F 20% @ 100°F	100% @ 60°F to 95% @ 95°F	100% @ 60°F to 95% @ 95°F	100% @ 60°F to 95% @ 95°F	100% @ 70°F to 45% @ 90°F	100% @ 70°F to 45% @ 90°F	100% @ 70°F to 45% @ 90°F	100% @ 70°F to 45% @ 90°F
	2 in/hr direct impingement	2 in/hr direct impingement	2 in/hr direct impingement	2 in/hr direct impingement	DNA	2 in/hr direct impingement	0.5 in/hr	0.5 in/hr	0.5 in/hr
	None	None	None	None	DNA	None	None	None	None
	None	None	None	None	DNA	None	None	None	None
R. S.	1/4 in H. R. S. per year	Total sea immersion	1/4 in H. R. S. per year	Negligible	1/8 in H. R. S. per year	Negligible	Negligible	Negligible	Negligible
impinge- 1 mph 101 to 101 to dia.	Direct impinge- ment. 45 mph wind, 0.001 to 0.125 in. dia.	LNA	Direct impinge- ment. 45 mph wind, 0.001 to 0.125 in. dia.	Direct impinge- ment. 45 mph wind, 0.001 to 0.125 in. dia.	DNA	DNA	Direct impinge- ment. 60 mph Rel. Vel., 0.001 to 1/8 in. dia.	Direct impinge- ment. 100 knots Rel. Vel., 0.001 to 1/8 in. dia.	DNA
	DNA	15 ft/sec to steel	DNA	15 g 11-18 ms	MIL-S-901C	15 g 11-18 ms	15 g 11-18 ms	35 g 5-15 ms	Ejection 30 g for 5 m sec
t	2 ft to dirt	2 ft to deck	2 ft to dirt	2 ft to dirt	2 ft to deck	2 ft to deck	DNA	DNA	DNA
	DNA	Negligible	DNA	DNA	±0.4g @ 5-55 cps	None	MIL-STD-810A	0.0125g ² /cps 2-2000 cps	Dependent on system
	Less than 1 v/m	Less than 1 v/m	1 to 2 v/m	1 to 2 v/m	None	300 v/m	300 v/m	300 v/m	Less than 10 v/m 30 sec
<div> <div>Weapon Must Only Survive</div> <div>Weapon out of container</div> <div>Weapon Must Function</div> </div>									

B

B

USES OF REPORT

The information displayed in Tables 1 and 2, indicates that there are 15 stockpile-to-target situations derived from Fig. 1 wherein the unit may be subjected to the 12 different chosen environments. This report presents these variables in Appendices B through J under individual topics. For example, the Appendix devoted to temperature does not discuss the environments between any two specific points where truck transportation would be used but rather gives information that is applicable to environmental conditions to be expected wherever truck transport is a probability.

An effort has been made in Tables 1 and 2 to keep the relationship between the various criteria in context. This method of subject treatment has been used so that in any testing involving two or more environments, the corresponding related criterion can be used. In the past, the maximum criterion from any cause was specified either separately or in conjunction with other maximum criterion. This has caused, for example, ordnance to be subjected to a combination of maximum dry summer temperature extremes and maximum tropical relative humidities as a combined test.

The numbers that are listed in either Tables 1 or 2 do not necessarily reflect values that the project manager will want to assign to the FAE weapon system. The values presented are as close to reality as the author can in good faith project. The project manager may, however, want to add a factor of uncertainty to any number herein provided. The function of this report is to indicate the level of exposure that should be "non-negotiable". If a contractor cannot meet the non-negotiable specification, then is the time to launch an investigation to define the penalties to performance and the Fleet in general if a waiver is granted. A comparison of the completeness of Tables 1 and 2 will indicate that the majority of environments need immediate work to determine the true "non-negotiable" values.

APPENDIX A

LITERATURE SEARCH

As background to this type of work, a literature search was inaugurated to cover the air-launched environments for ordnance. The Technical Information Department (TID) Library at NWC was thoroughly searched for reports pertaining to tethered flight criteria for ordnance. The search revealed a total of 240 reports listed under the computer term "Environment". The term, "Tests, Environmental" totaled 322 reports. The sources of the Defense Documentation Center were searched along with ASTIA and the Prevention of Deterioration Center. Masses of report abstract cards were secured and carefully reviewed. The same result was found in all cases. The reports pertained to laboratory exposure of individual items ranging from resistors and capacitors to full-size ballistic rocketry to chamber testing as per a given MIL-STD or specific contractor specification. For criteria determination purposes these reports were of no value. They all presuppose the knowledge of the basic environment. The information given in the specification is assumed to be full and correct. The basic information on which the specifications and standards are based is, in fact, very much open to question.

The combined literature search only brought to light information already known to the Environmental Criteria Determination Section of the Quality Assurance Division of NWC. There were a few surprises in that the search of TID report files unearthed references to earlier sources of some MIL-STD criteria than were earlier supposed but, in general, no new information that would shed new light on environmental criterion was uncovered.

Since the criteria was not to be found in the Navy literature system, the resources of the U. S. Army Test and Evaluation Command (TECOM) were utilized. The U. S. Army philosophy of environmental simulation dictates that any new piece of Army equipment from canned "C" ration to M-60 tank, must survive exposure to a season in the hot desert, cold arctic, and humid tropics. The mission of supplying these exposures falls to the U. S. Army Proving Ground, Yuma, Arizona, and the U. S. Army Tropical Test Center, Fort Clayton, Canal Zone, Panama. The meteorological data and support originates from the U. S. Army Electronic Research and Development Command, Fort Huachuca, Arizona. The test sites are Fort Greeley, outside of Fairbanks, Alaska, for the arctic; Yuma Proving Ground, Yuma, Arizona, for the desert; and Fort Clayton, Canal Zone, Panama, for the tropics. Since personnel from Yuma are primarily responsible for the reports and data submitted to the developmental agencies responsible for the inception and design of Army hardware, the reports on the performance of tested items can be found at the Yuma Proving Grounds and Aberdeen Proving Grounds, Maryland. The search of the Archives at the Yuma Proving Grounds revealed that the data in the

reports consisted primarily of "did the item function properly after exposure of a nonstandard time to an unknown environment". The Army philosophy is to expose the item to, for example, the cold arctic for any 30-, 15-, or 60-day period depending on number of projects, and personnel availability. After the exposure, whether it occurred during a cold snap, or a "warm" spell, the item is tested. If it functions successfully, it is given a clean bill of health. If it malfunctions, this also is reported.

The only data usually taken to give a clue to the exposure environment are meteorological. The "MET" team records all customary data to ascertain atmospheric conditions. Rarely, if ever, is any attention given to the actual temperature of the item tested. The meteorology is excellent, and can be obtained from the National Weather Records Center, Asheville, North Carolina, or in less formal form from Commanding Officer, Electronic Research and Development Command, Fort Huachuca, Arizona. These data have been found to be usable only as indicators of trends in ordnance exposure criteria. There are too many areas of missing information to rely on these data alone. The conclusion was reached that this line of endeavor was also virtually a dead end.

Previous to this assignment, the Environmental Criteria Determination Section at NWC had made contact with the then "Environmental Test Directorate" at the Wright Air Development Command, Wright-Patterson AFB, Dayton, Ohio. It is from the ancestors of this group that the majority of Military Specifications and testing documents have originated for all three military services. This organization developed the present MIL-STD-5272C for the U. S. Air Force after World War II. They were also responsible for the replacement specification, MIL-STD-810. When questioned on the procedure used to establish criteria used in this series of documents, it was revealed verbally, and in October of 1965 in written form, that the majority of the information was "best guess", or based on very narrow measurements for limited purposes. The publication, "The Evolution of USAF Environmental Testing," by V. J. Junker, (Technical Report AFFDL-TR-65-197), is the most concise and comprehensive document covering this subject. Since the Navy relies so heavily on this family of specifications, it would be well if every Naval Air Systems Command engineer obtained and read a copy of Mr. Junker's report.

The most usable data from Wright Field is centered around aircraft vibration. The preliminary work done in this area was to support the criterion found in MIL-STD-810. In essence they have obtained information for turboprop transports, jet bombers, Century Series jet fighters, and helicopters. These data are subdivided into various aircraft locations, such as "outer one-third of wing, inner two-thirds of wing, aft quarter of fuselage, forward quarter of fuselage, center half of fuselage". Needless to say, all the information is on Air Force type aircraft, but the general levels are a good indication of energy levels to be found on Navy aircraft of the same general classification.

The contacts at Wright Air Development Command led to contacts at the U. S. Army, Natick Laboratories, Natick, Mass. The predecessors of the Natick Laboratories were responsible for the information used to write the worldwide extreme environmental specifications. The scientists at the then U. S. Army Quartermaster Research and Development Command were, in the majority, natural science types. An excellent job of collecting worldwide weather or meteorological extremes was done with the philosophy that these extremes are the limiting factors, not the design criteria for worldwide use items of Army issue, from a soldier's personal equipment to the large engines of destruction. When the work was done in the late 1940's and early 1950's, it was recognized as being the first step toward an integrated system of Military Specifications. The philosophy was to have as few MIL-STD documents as possible to preclude confusing the purchasing agent and contract administrator when a contract was assigned to industry. It must be remembered that, in this era, the complex weapon or weapon system was just starting to come off the drawing board. The propeller-driven aircraft and subsonic jet aircraft were still the first line of defense.

Presently, the Natick Laboratories, of the Army Material Command, have been working on worldwide analogues for the major test stations and proving grounds in the U. S. Army Test and Evaluation Command. For example, the weapon that survives and functions at Yuma Proving Grounds is good for use in the Punjabi Desert, the African Desert, etc. From these worldwide analogues it is possible to obtain an exposure analogue of deserts in the United States or any other desert area. This in itself does not answer environmental exposure questions, but it does reinforce the usefulness of any environmental exposure information conducted in the Continental United States.

The above installations constitute the sources of the vast bulk of the environmental literature. There are others, such as North American Aviation and McDonnell-Douglas Aircraft, that have contributed pieces to the literature. However, the pieces of environmental information that come from the contractors are filed in the library of one of the TECOM or WADC installations. On the whole, the reports from contractors consist of "what happened to a specific resistor" while subjected to MIL-STD-5272C type of testing and not "what will Fleet usage require".

APPENDIX B

TEMPERATURE

The major advantage, when designing for Southeast Asia instead of worldwide expectancy, is that the envelope of extreme temperatures is narrowed considerably. In general, the area from the equator to the tropic of Cancer is typified by a constant band of air temperatures between 70 and 85°F. Since the air temperature band is not wide, this moderates the possible variance of ordnance temperatures in the region. For example, there can be no ordnance temperatures of -65 or 165°F when the secondary thermodynamic driving force tends to stabilize the air temperature level between 70 and 85°F. (Primary driving force is insolation.)

According to the most comprehensive work done to compile air temperature information reported for Southeast Asia, (Ref. 1), the month with the highest air temperature expectancy is April. The absolute maximum air temperature recorded in Viet Nam in April is less than 110°F. This is for a small anomalous region in the panhandle of North Viet Nam. In the South Viet Nam region the absolute maximum air temperature measured is less than 105°F.

The temperature expectancy of the nominal 15 degrees north latitude band is characterized by a bicuspidate hot season. Since the sun is directly overhead twice a year, instead of nearly overhead once per year as in the United States, there are multiple possibilities for maximum insolation. In Southeast Asia the monsoon rains in large part negate one of the two cusps. In general this cusp is the August-September peak. Therefore, the temperature year is characterized as in the following example.

January, February, and March can be mild and "dry". April and May are "dry" and hot since the sun has now moved from over the equator on 21 March to the tropic of Cancer on 21 June. June, July, August, and about the first 2 weeks in September are the rainy season. By the time the monsoon wind has reversed in mid-September, the sun has pulled back over the equator (21 September). Therefore, the September, October, and November "dry" season is not conducive to elevated air temperatures. Of course on 21 December the sun is at its farthest point south (tropic of Capricorn). The "hooker" in the above is that for all Southeast Asia areas it is simply not true. The "dry" and "rainy" seasons are defined by the direction of the monsoon. Therefore, if the land mass is exposed to a "wet" wind, it will experience a rainy season. If the moisture is released from the monsoon, then the land down-wind will experience a "dry" season. When the monsoon reverses, the wet land area dries out and the "dry" area is mired in mud.

Measurements done on 70-pound Naval ordnance and miscellaneous Naval fuses by NWC at the Naval Magazine, Subic Bay, Republic of the Philippines, are used as the basis for the series of "dump storage" high temperature projections. The ordnance was exposed to direct insolation starting in September 1966. Continuous time-temperature records have been derived. (The measurements are still in progress.) The Table 2 value for dump storage reflects a conservative interpretation of the interim results.

The non-dump storage projections are based on the work published by NWC on the statistical distribution of magazine air temperature (Ref. 2). Information from the same sources, though unpublished, was used to define the continental United States storage temperature portion of the Table 2 information.

The truck and rail transportation high temperature projections are based on maximum temperatures measured by NWC, though unpublished, and the U.S. Army Natick Laboratories (Ref. 3). The measurements have all been done in the pure desert. Therefore, the temperatures quoted are extreme when equated to Southeast Asia. All projections concerning ship-board temperatures are derived either from work done by the then Bureau of Naval Weapons, Code RMMP-32 (Ref. 4), unpublished continuous time-temperature information measured by NWC on DD and LSMR type ships, or the temperature log books from all classes of combatant ships, that under instructions from Chief of Naval Operations (CNO), have been sent to NWC by all ship commands.

The cold weather limits of a Southeast Asia environmental criteria determination have to take into consideration any widening of the temperature envelope caused by manufacturing locations in the United States. In general, all minimum temperature values of Table 2, from transportation through storage, reflect the continental United States cold situation. In general, the sources of data from which the minimum temperatures were derived are the same as those stated above. The bulk of specific transportation and storage temperature information has been measured or collected by NWC and at present the majority of these data are unpublished, though available in preliminary form to all who would expend the effort necessary to review them.

APPENDIX C

RELATIVE HUMIDITY

The relative humidity (RH) exposure of the Southeast Asia ordnance will be no different than the exposure in some temperate zone areas. The design maximum in all cases is 0.035 pounds of water per pound of dry air. This quantity is equivalent to 95°F and 95% RH. This criterion is severe and such exposure will not be the rule during the item's service life.

The normal situation in the tropics is 75 to 85°F with relative humidities of 100% to 85%. In the dry season, the temperature remains about the same (75 to 85°F), but the relative humidity can drop as low as 50%.

The low temperature-relative humidity design situation can be met by using the "rule of thumb" that the RH is 100% for any temperature below 35°F, in fact, the 100% RH situation can be generally assumed to exist from 70°F or lower.

The major humidity caused problems will be experienced during transportation and storage. The hydraulic pressure of high temperature and humidity are experienced during these situations because the differential expansion of parts of an item can provide the path for water entry. Then the cooling exhibited by the nighttime portion of the diurnal cycle tends to condense the airborne water onto parts of the hardware. Enough of these cycles can fill an item full of water. For example, the author has examined cans of previously unopened 20mm aircraft ammunition that had been corroded into a solid mass by moisture entry apparently as described above. Also, Very pistol ammunition, ruined by moisture pickup by the hygroscopic pyrotechnic mix at NM Guam, has been observed.

The conditions to be expected under the combat handling and launch-to-target situations may or may not be as severe as the storage situation. The 0.035 pounds of water per pound dry air absolute humidity criterion is still extreme.

APPENDIX D

PRECIPITATION

Precipitation usually interferes with the functioning of ordnance by restricting the physical movement of the item, or as a vehicle for another type failure; i.e., freezing dirt or moisture ingress, etc. In general, for a weapon designed for use in Southeast Asia, the precipitation modes can be reduced to rain only. The other forms may be evidenced between the time of manufacture and the time of embarkation from the continental United States. During the continental United States exposure, the ordnance will be in covered storage, a closed van truck, or railroad boxcar. Therefore, there will be no exposure directly to solid precipitation during the life of the round.

The unit has a high probability of exposure to rain as soon as it leaves the continental United States. Transportation will no longer necessarily be in van type trucks, but may be in open cargo trucks. Storage may be in a storage dump without so much as a rudimentary roof. During at-sea-transfer, combatant handling, or during aircraft carry, rain exposure in Southeast Asia will be the rule rather than the exception.

There have been exposures greater than 2-inches per hour recorded in the tropical regions of the world. However, any rain of 2-inches per hour will lead to flooded conditions and a virtual sheet of water engulfing the ordnance. This being the case, there is no practical value in specifying a greater rate of flow. (At 2-inches per hour flow rates, the oxygen is partially depleted from the air by the falling water, and some difficulty may be experienced in breathing.)

Usually the tropical downpour is not as long and hard as rainstorms associated with portions of the Midwestern United States. In general, the rainstorm system can be seen and its unique sound heard as it progresses out of the distance toward the observer. When it strikes, it rains violently for a short while and then subsides. This type of rainstorm generally is evident from June through September depending on the direction of the monsoon wind and the general terrain. From October through April, or the dry season, the rain will not be absent, but it is not usually intense, nor lasting. During this time in the tropics, it is not uncommon to observe a black cloud drop a narrow strip of rain as it passes over. In one instance the north side of a street was drenched while the south side was dry.

APPENDIX E

CORROSION

Corrosion is one of the big unknowns in detailing the stockpile-to-target sequence. At present there is no general matrix in which corrosion as a whole can be placed. Many excellent institutions have done fine investigative work as to the manner in which a particular metal corrodes; however, the information gained from one alloy is not necessarily usable on another.

In the MIL-STD system, the testing for corrosion resistance does not differentiate between the different modes of corrosion. For example, nowhere is galvanic, acid gas, biological, or interstructure corrosion even mentioned.

In this document, no more definitive statement on corrosion can be made than to try to place it into time and geographical context. It is known that corrosion is a time dependent phenomenon. The various modes of transportation all have in common the fact that they are transient, and not permanent repositories of the ordnance. Corrosion cannot be too severe during transportation since the element of time is relatively short. Therefore, in the context of the whole stockpile-to-target sequence, this corrosion is deemed negligible.

During storage, however, the time factor can be extended. Therefore, the most severe situation imaginable would be in tropical storage. Again, the only statement that can be made is one such as "severe". In Table 2 the severity of the potential for corrosion is expressed as the rate of dissipation of hot rolled steel when exposed. The use of the dissipation rate of hot rolled steel is purely arbitrary.

The other situations in the stockpile-to-target sequence lie between the transient, short time of exposure "negligible", and the aggravated long time of exposure dump storage "severe".

APPENDIX F

SAND AND DUST

The sand and dust environment is usually not well understood. The supposition that the present MIL-STD sand and dust testing methods answer the question of abrasion resistance has lulled the designer into a false sense of security. The MIL-STD criterion calls for pure silica to be blown at velocities of 7 to 30 miles per hour.

Work attempted at the Naval Weapons Center has indicated that samples of soil collected at random from worldwide locations contain more abrasive major portions than silica. The following is very preliminary, but illuminating.

"ANALYSIS OF SOILS FROM VARIOUS AREAS OF THE EARTH"

By Edward Kuletz

A limited literature search on the soils of the world revealed that the majority of the data was on the top-most portion of the earth's surface. It is the so-called sub-soil, that portion beneath the humus layer, which causes seemingly the most damage to jet aircraft engines, to military vehicles, to ordnance items and to general storage areas. In many areas, this so-called sub-soil is or becomes the top-soil which comes into active contact with military hardware at airfields, roads and open terrain. Even in areas where the climate is tropical in nature, problems occur during the seasonal dry spells. During these periods, the wet clay-like material develops into a fine, dust-like substance which is extremely irritating, erosive and contaminating (such as the stopping-up of various filter systems).

There is a great variation between soil samples from southern California and the southeast Asian area. Tests, which were performed on an infrared spectrophotometer, indicated that the principle constituent in the samples from the southern California area was silicon dioxide (SiO_2) and in the samples from the southeast Asian area it was China clay ($\text{Al}_2\text{O}_3 \cdot 2\text{SiO}_2 \cdot 2\text{H}_2\text{O}$). A chemical analysis showed that the samples from southern California contained approximately 1 to 8 percent of iron oxide in the form of Fe_3O_4 while the samples from southeast Asia contained 4 to 13 percent of iron oxide in the form of Fe_2O_3 .

Eleven soil samples were analyzed by the Engineering Evaluation Branch (Code 5516) of the Naval Weapons Center. The methods of analysis included the standard quantitative chemical analysis tests and the use of the atomic absorption spectrophotometer. A summary of results of the tests is given in Table 3."

TABLE 3. Summary of Soil Analysis By Code 5516

Soil (Area)	Iron Oxide Fe_2O_3	Al Oxide Al_2O_3	Silicon- Dioxide SiO_2	Ignition Loss (H_2O)	Density g/cm^3	Particle Size Microns
DaNang	8.69%	7.61%	80.21%	3.35%	2.735	20.0
Korat, Thailand	3.97	8.90	77.37	6.93	2.654	27.6
Subic Bay	15.34	29.22	39.07	13.27	2.851	14.4
Sea-Tac, Wash.	3.70	14.12	66.60	8.30	2.543	34.5
Anchorage	5.69	15.84	64.94	4.19	2.728	35.4
Harrisburg, Pa.	5.35	13.22	68.41	7.46	2.711	10.5
Fairfax, Va.	7.28	14.16	65.18	6.39	2.735	18.6
White Horse Yukon	3.13	13.22	68.14	3.96	2.476	20.4
Yuma, Ariz.	1.30	5.80	82.07	2.75	2.646	47.0
Tanana Valley, Alaska	3.37	7.15	81.43	1.52	2.690	45.0
Alcan Hiway Composite	6.48	14.51	56.7	7.91	2.744	7.5

The foregoing statement can easily be interpreted as indicating that the 140 mesh silica flour criterion needs revision. Any sample used to test the imperviousness of any item to sand and dust must include the following:

15 to 30% - Al_2O_3 (Corundum)

5 to 10% - Fe_2O_3 (Jeweler's Rouge)

60 to 80% - SiO_2 (Silica)

The experience of the desert dweller at the Naval Weapons Center, China Lake, California, indicates that during a sandstorm, the wind

velocity can attain values of 30 to 45 miles per hour. This same experience has shown that particles as large as 1/16 and 1/18-inch diameter are thrown into the air when the extreme wind velocities persist.

The dirt environment will be the most severe during the truck transportation and aircraft carried phases of the unit's life. The unit must not only be able to withstand the previously stated criterion, but the impact velocity can increase by the added velocity of the carrying truck or combat aircraft. In the case of the truck situation, the item may or may not be enclosed in a container. In the case of a carrying aircraft, the item is ready for use and fully exposed.

The aircraft situation is the most extreme for portions of the item facing forward; i.e., fuse or ogive. Since conventional aircraft take-off and land into the wind, they will also expose the item's front surfaces to the relative velocity of the aircraft to the air. Therefore, the dirt will impinge at the higher velocity, (this phenomenon is responsible for the high incidence of sandblasted cars as they enter California via U.S. Highway 60 through Indio on up the Whitewater Grade to Banning).

Severe bombardment by all size particles from one micron to 1/8-inch diameter is probable during dump or semi-covered storage. The maximum wind conditions will also be experienced. The only extenuating circumstance is that the item is in its container during the long-time exposure.

During combatant handling at a forward helicopter or propeller-driven aircraft airstrip, the item would be exposed to prop wash, natural wind conditions, and particle impingement induced by passing vehicles. It is here that the item could experience the most severe sand and dust deterioration.

During rail and air transportation, the exposure to sand and dust is negligible. The aircraft or boxcar is a closed entity. The air velocity inside is negligible; therefore, no dirt will "move".

APPENDIX G

SHOCK

Shock and drop are handled separately in this report because in the final analysis not enough data exist for complete correlation. Shock is herein defined as a single blow received in a dynamic situation such as movement on a truck or other vehicle, or a blow received while the ordnance is being transferred from one ship to another. Drop is herein defined as the shock experienced from accidentally dropping the ordnance.

The shock criterion as published for most situations is somewhat incomplete. The complete definition of the shock parameter requires shock force, time duration of the force, and the force pulse shape. The vast majorities of shock data published delete one or more of the essential elements.

The shock criterion is derived in general from Ref. 5, "Fundamentals of Guided Missile Packaging," for the transportation and handling sections. In general, the only criterion therein presented is the energy level and the time duration. Since this information is meaningless without a specified wave shape, the sawtooth wave has been arbitrarily specified by the author. The sawtooth wave was chosen since it exhibits all frequencies.

The at-sea transfer impact of 15 feet per second velocity is a composite of results of interviews conducted with ammunition ship officers. The transfer speed between ships was judged to be approximately 20 miles per hour (vehicle road speed at NWC) which, when accelerated by the pendular load movement, would attain the impact velocity stated. This value is a visually founded assumption, however, and verification has not been recorded by instrumentation.

The criterion projected for propeller driven aircraft is derived from World War II information obtained by using Circa 1945 shock recording equipment. The "test" vehicles were the venerated TBF, F4U, F6F generation of Naval aircraft. The value presented is for arrested carrier deck landing. These data are in urgent need of rechecking and updating.

The helicopter criterion is the projection of NWC, Code 45334. The projection is based on information being obtained from the HU-1E type helicopter. For more detailed information this Code should be contacted.

The "launch-to-target" projections are based on the agglomerate experience gained on prior NWC developed air-launched and free fall weapons. The values are highly negotiable if a more worthy source of information is available.

APPENDIX H

DROP - NO DAMAGE

In all steps of the stockpile-to-target sequence there is a possibility that a given piece of ordnance will be dropped. The agonizing decision for the environmentalist is to determine from what height the unit will probably be dropped and yet be expected to survive intact.

It is known that a 250-pound, or heavier, item must be lifted by machinery, or many strong sailors' backs. Therefore, the non-catastrophic drop height will be progressively less as the weight of the item is larger. For example, a box of 30-caliber ammunition can and will be thrown off of the back of a 2 1/2-ton truck. The drop criterion for a box of 30-caliber ammunition should be approximately 10 feet to dirt. However, a 250-pound device cannot be lifted by a single sailor; therefore, it will require two or more sailors to handle it. The height above the surface to which the unit will be lifted is not excessive due to physical limitations of the men. More times than not mechanical means are used to load and unload units, or pallets of units of large size. In the Naval logistical framework, most items are palletized into loads of one to 1 1/2-tons each.

If it can be determined that the item is to be handled by mechanical means during transportation, then the drop height probabilities will be reduced considerably. Since the forklift truck is the standard piece of material handling equipment, it will be discussed further.

The probability of dropping a piece of cargo goes up as the operator's workload increases. In the wartime situation, the 12-hour day is not uncommon. The magazine personnel are extremely overworked and understaffed. At the forward airfields, the supply situation sometimes approaches chaos. Non-sophisticated ordnance is in fact thrown around as if it were inert. However, the more complicated the unit appears, or the more elaborate the missile container, the more care is given it by the overworked troops.

A semiskilled forklift operator will rarely drop any palletized load more than 4 to 6 inches on restacking or loading. The usual drop occurs when the operator applies the brakes short so that the pallet will slide into place. Any drop during the slide higher than 4 inches will cause the loss of control of the pallet load. Therefore, the drop - no damage height, if set from forklift experience only, would be 6 inches. Since the probability of manual movement is real, the drop - no damage criterion must recognize the fact. Therefore, the general criterion is 1 to 2 feet onto the appropriate surface.

The only exception is during loading into a commercial cargo ship by civilian longshoremen. The probability does exist that a net load of units can be dropped 5 feet to the bottom of the hold, seven decks down, when the signals get mixed up between the "guide" and the donkey engine operator.

APPENDIX I

VIBRATION

The vibration regime to which the FAE system will be subjected is somewhat complex, and very nearly undefined by actual in-flight measurement.

The transportation environment is derived from accepted, though by no means verified, information reported in Ref. 5. The information from which Ref. 5 was compiled was derived in the "period of infancy" of vibration measurement. The accelerometers and tape recorders of that day were very much lacking in the necessary sophistication. The criterion was written in specification form conforming to the capabilities of the vibration reproducing machinery of that time.

Needless to say, the information requires updating urgently. Nowhere in the majority of criteria stated in Table 2 is random vibration even mentioned. Yet the question remains "is the true vibration spectrum only sine wave".

It is obvious that in all storage situations there will be no vibration spectrum since storage is a static situation. The shipboard storage criterion is derived, for want of a better source, from MIL-STD-167 (Ships). This specification was written as a result of ships sustaining broken engine casting, turbines, drive shafts, etc. from general use during World War II.

Since the propulsion gear of a ship is the major source of vibration, the largest energy levels might be expected to prevail in this region. Therefore, it is assumed (though not proven), that magazine-stored ordnance units will not be exposed to any energy levels greater than those revealed in MIL-STD-167 (Ships).

The air-carried vibration spectrum is also open to discussion. The helicopter information is distilled for use in MIL-STD-810 from original work done at the Wright Air Development Command, Wright-Patterson Air Force Base, Dayton, Ohio, on the H-37A helicopter. The vibration spectrum of the HU-1E series helicopter may or may not be equivalent to that of the H-37. Work is now in progress at the Naval Weapons Center to measure the spectrum of the HU-1E series helicopter as it pertains to carried weapons.

The spectrum delineated for the propeller-driven aircraft is a supposition based on interpretation into random vibration terms of the experience measured on World War II type aircraft in the late 1940's and early 1950's. In general, the "number" is valid for propeller-driven and subsonic jet aircraft such as the A-4 series.

APPENDIX J

RADIO FREQUENCY HAZARD

The Navy has been plagued spasmodically since World War II with isolated incidences of aircraft rockets being "magically" ignited during installation on the launchers of strike aircraft. The cause was determined to be the radio frequency (RF) energy from radio and radar transmitters. The phenomenon was most noticable on the flight deck of an aircraft carrier. Measurements of the RF field strength on the deck of an aircraft carrier have lead to the criterion of 300 volts per meter RF energy.

At first this seems to be an insurmountable problem when it is realized that any electrically initiated piece of ordnance is susceptible, and that the resonant quarter-wave antenna for radio frequencies is on the order of 1 foot or less. Two major physical phenomena seem to come to the aid of the designer. The most important is the fact that any electrical circuit, that is completely enclosed in metal (i.e., the hull of a ship), cannot be affected by RF energy. The second is that the field strength of a signal drops off as the distance from the transmitter increases. The near field drops off to the second power. Therefore, the field strength of even the most powerful (50,000 watts) broadcast station is less than 2 volts per meter at a distance of 1 mile. In general, the "rule of thumb" is that at 1/10 mile no trouble is to be expected.

For more detailed information of either narrative or technical nature contact NWC, Code 5525. This unit, Systems Electronic Design Branch, has been studying the basics of the problem on a continuing basis.

In general, the Table 2 values are predicated on the two above mentioned physical phenomena, Faraday shielding, and drop off of field strength with distance. The values below 10 volts per meter are predicated on the distance of separation of the ordnance and any high power transmitters. The "none" entries reflect the Faraday shielding of a ship's magazines. The maximum 300 volts per meter criterion reflects the maximum measured field strengths on the flight deck of an aircraft carrier when all search radar, liaison and command transmitters, and aircraft transmitters may be in use simultaneously. It seems to be at this time that the problem is most ill defined and serious.

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13. ABSTRACT The stockpile-to-target sequence for FAE with emphasis on use in Southeast Asia is discussed. The criterion associated with manufacture in the United States, transportation to, and use in Southeast Asia are presented. Environmental criterion are presented where known. Where unknown, assumptions or projections are given based on the author's best educated guess. Technological support is given for the criterion presented. The report includes 1 figure and 3 tables.			

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14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Environment Environmental Criteria Temperature Relative Humidity Precipitation Corrosive Atmosphere Sand and Dust Shock Drop - No Damage Vibration Radio Frequency (RF) Radiation Hazard Environmental Philosophy Stockpile-to-Target Sequence						

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